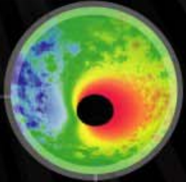
structure and evolution of the universe

BEYOND EINSTEIN:

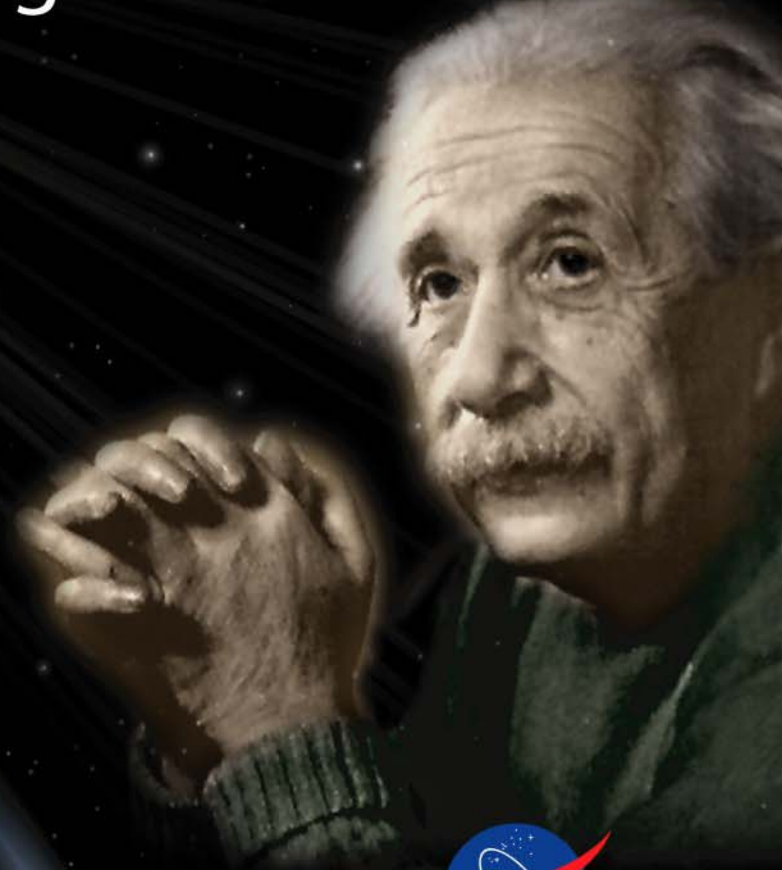
from the big bang to black holes

WHAT POWERED THE BIG BANG?



WHAT HAPPENS AT THE EDGE OF A BLACK HOLE?

WHAT IS DARK ENERGY?



National Aeronautics and Space Administration

SEU Science

. . . accretion disks, Big Bang, black holes, cosmic magnetic fields, cosmic rays, dark energy, dark matter, extreme environments, gamma-ray bursts, jets, large-scale structure, microwave background, neutron stars, nucleosynthesis, relativity, supernovae, . . .

10^{-25} cm (UHE Cosmic Rays) to 10^{15} cm (Gravitational waves)

Great Decade:

CMB fluctuations (COBE, BOOMERanG, MAXIMA, MAP, . . .)
Gamma-Ray Bursts (CGRO, Swift, . . .)
Ubiquity of black holes (Chandra, ASCA, HST, . . .)

Top priority: Answer the most profound questions raised, but not answered, by Einstein.

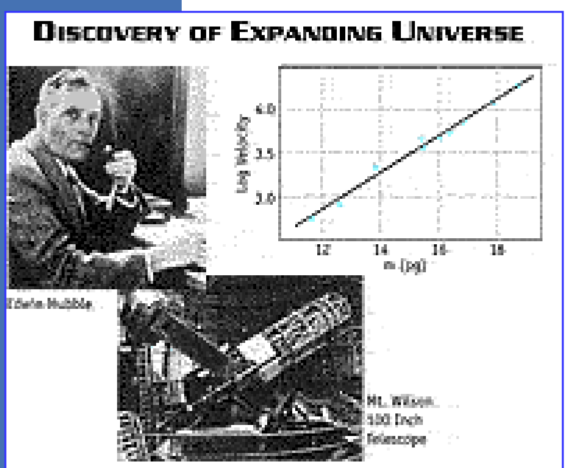
Einstein's Predictions

Three startling predictions of Einstein's relativity:

- **The expansion of the Universe (from a big bang)**
- **Black holes**
- **Dark energy acting against the pull of gravity**

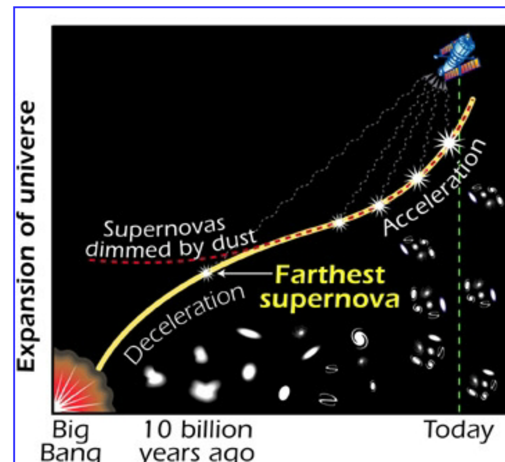
Observations confirm these predictions . . .

. . . the last only four years ago



Hubble discovered the expanding Universe in 1929

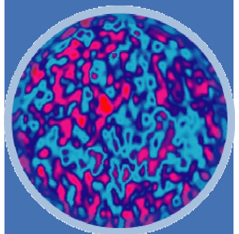
Black holes found in our Galaxy and at the center of quasars over the past three decades



Evidence for an accelerating Universe was observed in 1998

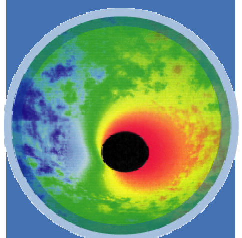
Completing Einstein's Legacy

Einstein's legacy is incomplete, his theory fails to explain the underlying physics of the very phenomena his work predicted



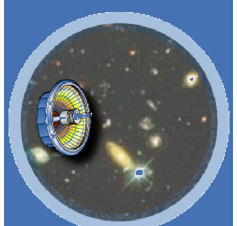
BIG BANG

What powered the Big Bang?



BLACK HOLES

What happens at the edge of a Black Hole?



DARK ENERGY

What is the mysterious Dark Energy pulling the Universe apart?

Beyond Einstein will employ a series of missions linked by powerful new technologies and common science goals to answer these questions …

… and launch the revolution of the 21st century!

Realizing Science Beyond Einstein

Three inter-linked elements that work together:

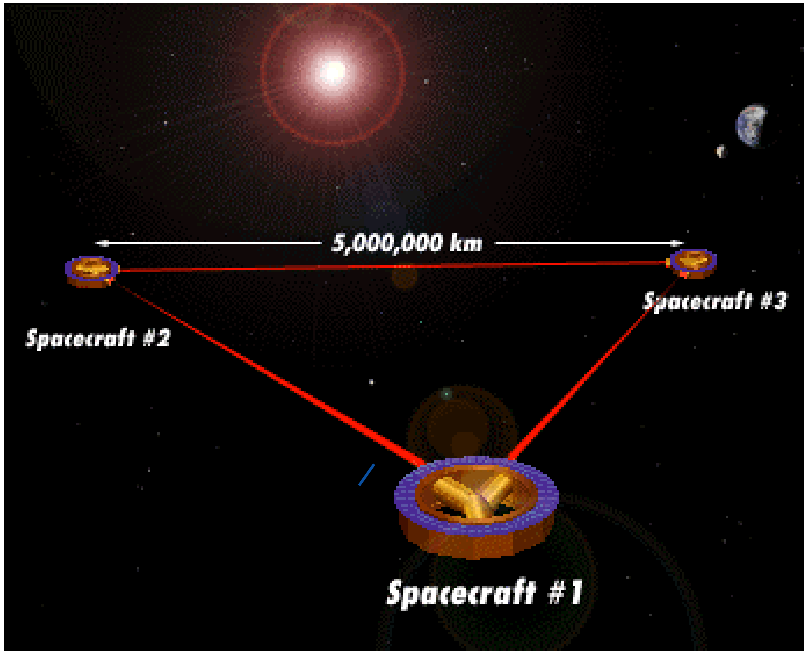
1. Einstein Great Observatories providing breakthrough increases in capabilities to address all Beyond Einstein science:
   - LISA: Gravitational waves from merging black holes and the early Universe
   - Constellation-X: Spectroscopy close to the event horizon of black holes and place constraints on dark side of the Universe

2. Einstein Probes to address focused science objectives:
   - Determine the nature of the Dark Energy
   - Search for the signature of inflation in the microwave background
   - Take a census of Black Holes of all sizes in the local Universe

3. A technology program, theoretical studies and an education program to inspire future generations of scientists and engineers towards the vision:
   - Directly detect the gravitational waves emitted during the Big Bang
   - Image and resolve the event horizon of a Black Hole

Laser Interferometer Space Antenna (LISA)

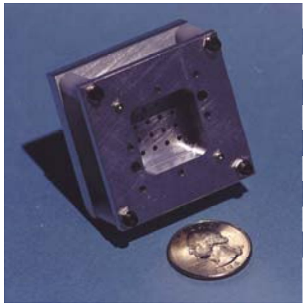
Joint ESA-NASA project



LISA uses a laser based Michelson interferometer to monitor the separation between proof masses in separate spacecraft

- **Three spacecraft separated by 5 million km**
- **Each spacecraft includes two freely falling test masses with drag free operation**
- **Distance <u>changes</u> measured with precision of 4 ppm RMS over 100 seconds**

Flight demonstration of disturbance reduction system ST-7 on ESA SMART-2 mission in 2006

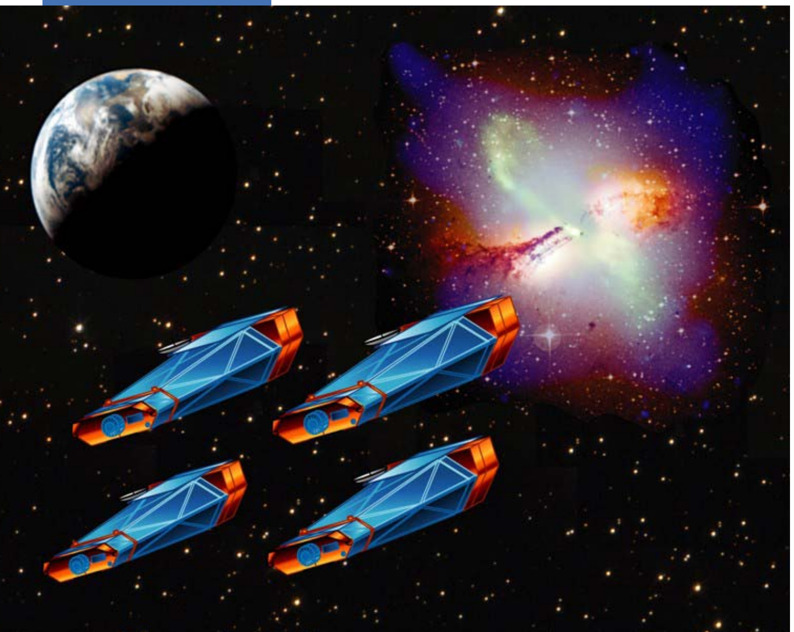


micro-newton thrusters

LISA, the first space-based gravitational wave antenna, was given strong endorsement by US National Academy of Sciences McKee-Taylor and Turner Committee Reports

Constellation-X

Use X-ray spectroscopy to observe



- Black holes:
  - Probe close to the event horizon
  - Evolution with redshift
- Dark side of the Universe:
  - Clusters of galaxies and large-scale structure
- Production and recycling of the elements:
  - Supernovae and interstellar medium

- 25-100 times sensitivity gain for high resolution spectroscopy in the 0.25 to 10 keV band
- Four satellites at L2 operating as one with advanced X-ray spectrometers

Enable high resolution spectroscopy of faint X-ray sources

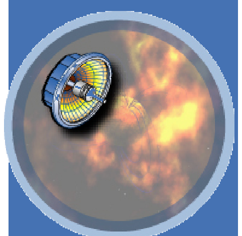
Constellation-X given strong endorsement by US National Academy of Sciences

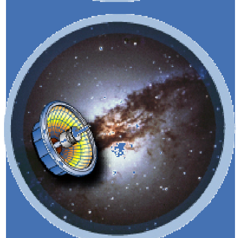
Einstein Probes

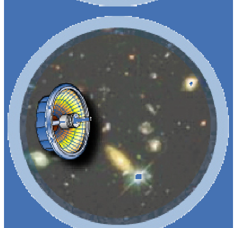
Three focused missions, each designed to address a single high priority science question

- **Priority and science topic determined via NASA strategic planning process, using National Academy recommendations**
  - **Dark Energy Probe**
  - **Inflation Probe**
  - **Black Hole Finder Probe**

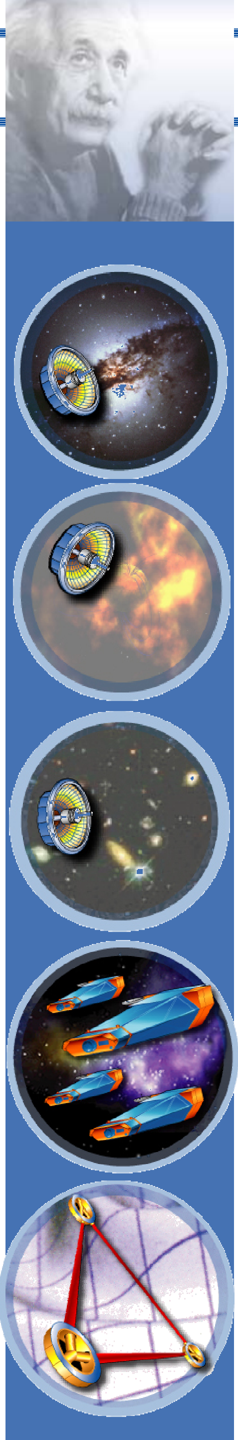
- **Competed Principle Investigator missions**
  - **Implementation approach determined by peer review**
  - **Launched every 3-4 years**
  - **$350-500M class missions**

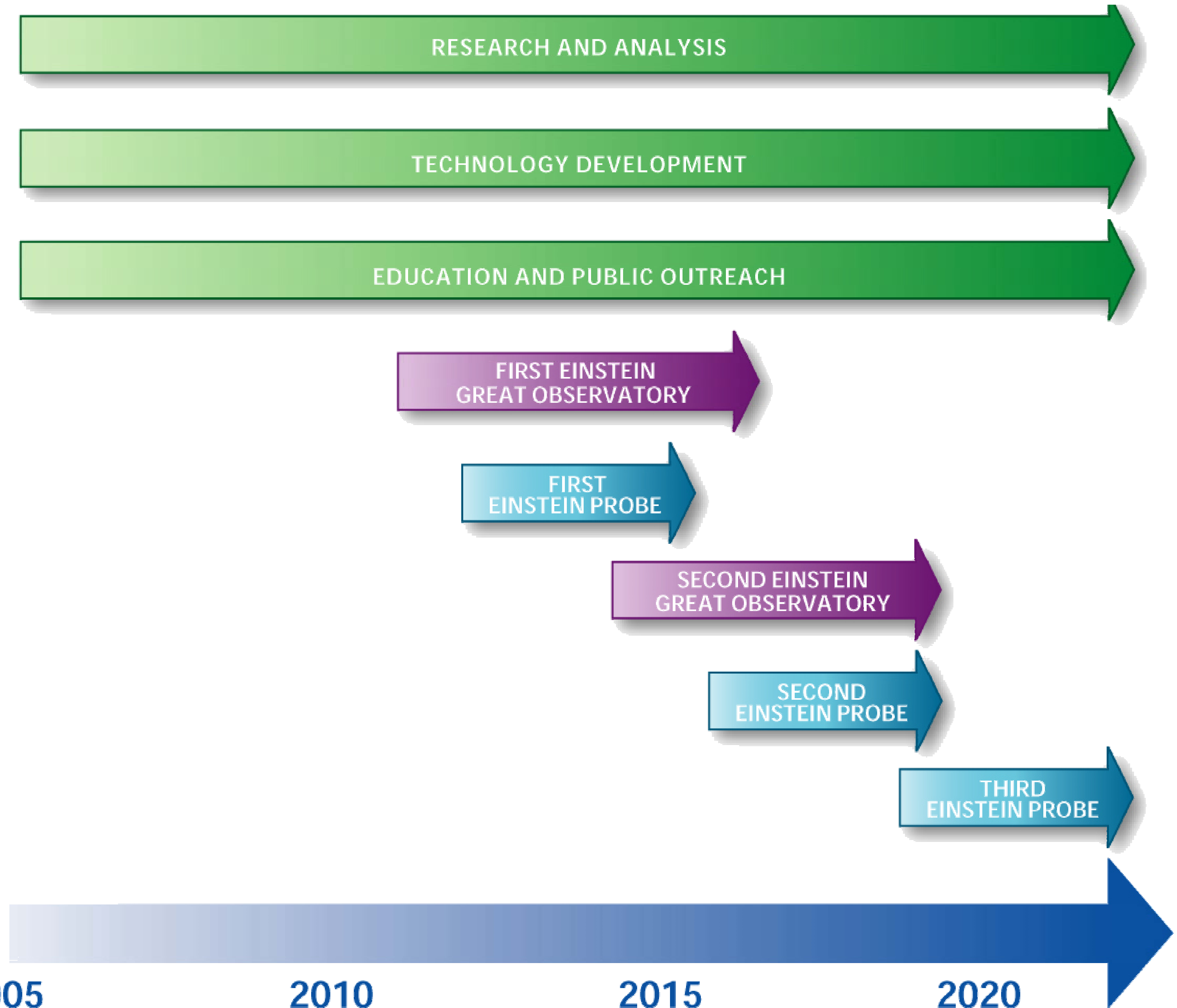


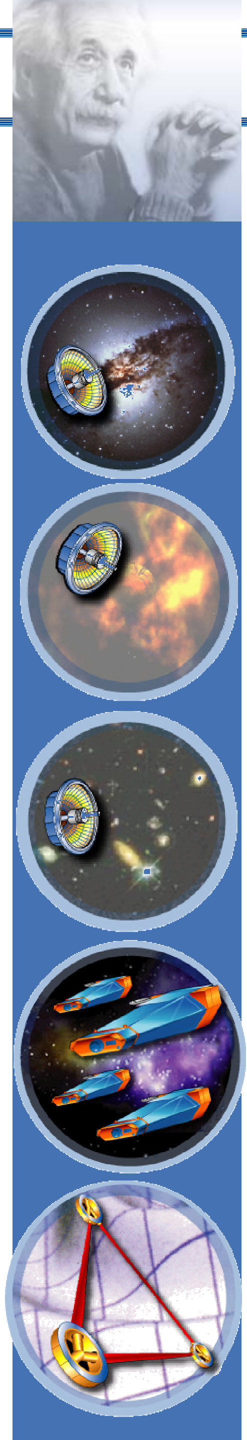




Beyond Einstein Timeline

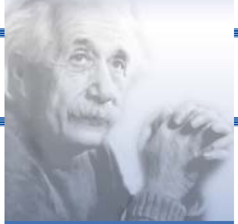






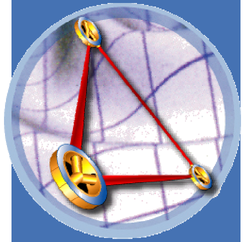
Next Steps

- **Beyond Einstein Initiative has been proposed in the President's FY04 budget request to Congress**
  - **Awaits action by Congress later this year**
  - **Includes LISA (2011), Con-X (2013,2014)**
  - **Funding for Einstein probes begins in 2007**
- **Technology Readiness and Implementation Plan (TRIP) review of LISA and Con-X**
  - **Complete TRIP review and incorporate results into project planning**
- **Initiate Einstein Probe mission concept studies**
  - **Call for proposals released February 10; proposals due June 13**
  - **After 1 year may have insight into ordering of Probes and options for implementation or partnering**
  - **Technology development and mission formulation awaits additional resources**



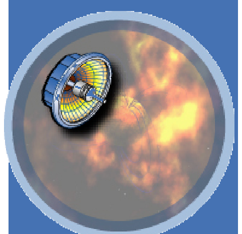
TRIP Review

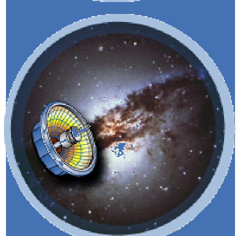
- **Review is complete and independent assessment teams reported to NASA HQ in late April**
  - **Con-X team briefed on results on May 2**
- **The TRIP Review has multiple objectives**
  - **Identify the key mission milestones and challenges.**
  - **Determine the current mission technology level and the feasibility of the mission technology roadmap to achieve readiness for flight.**
  - **Assess the feasibility of the plan for completing mission formulation**
  - **Assess the feasibility of the plan for mission implementation, including the overall mission cost, schedule and the realism of the proposed launch dates.**

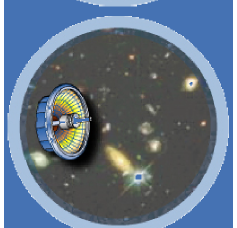


Einstein Probes NRA

- **Solicit mission concept studies for Einstein Probes**
  - **Mission concept must address the science objectives of one of the three Einstein Probes**
  - **Proposals due June 13**
- **Select ~3 mission concept studies per Probe**
  - **Total funding ~$1M / year for up to two years**
- **Two types of Dark Energy Probes**
  - **Complete mission**
  - **Contribution to DOE's Supernova Acceleration Probe (SNAP)**
- **Future plans for Einstein Probes**
  - **NRA for technology development (as needed)**
  - **AO for PI-led missions (as budget and technology permits)**
  - **Launch no earlier than ~2015 without additional resources in 2005-2007**







Space Science Enterprise
Agency Vision and Mission

The NASA Vision: "To improve life here, to extend life to there, to find life beyond."

The NASA Mission: "To understand and protect our home planet, to explore the universe and search for life, to inspire the next generation of explorers . . .
as only NASA can."

Space Science Vision

- How did the universe begin and evolve?
- How did we get here?
- Where are we going?
- Are we alone?

Space Science Themes

- Astronomical Search for Origins
- Structure and Evolution of the Universe
- Solar System Exploration
- Mars Exploration
- Sun Earth Connection

The Space Science Vision fully supports the NASA Mission

Agency Budget

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FY 2004 PRESIDENT'S BUDGET REQUEST

(NOA IN RY M)

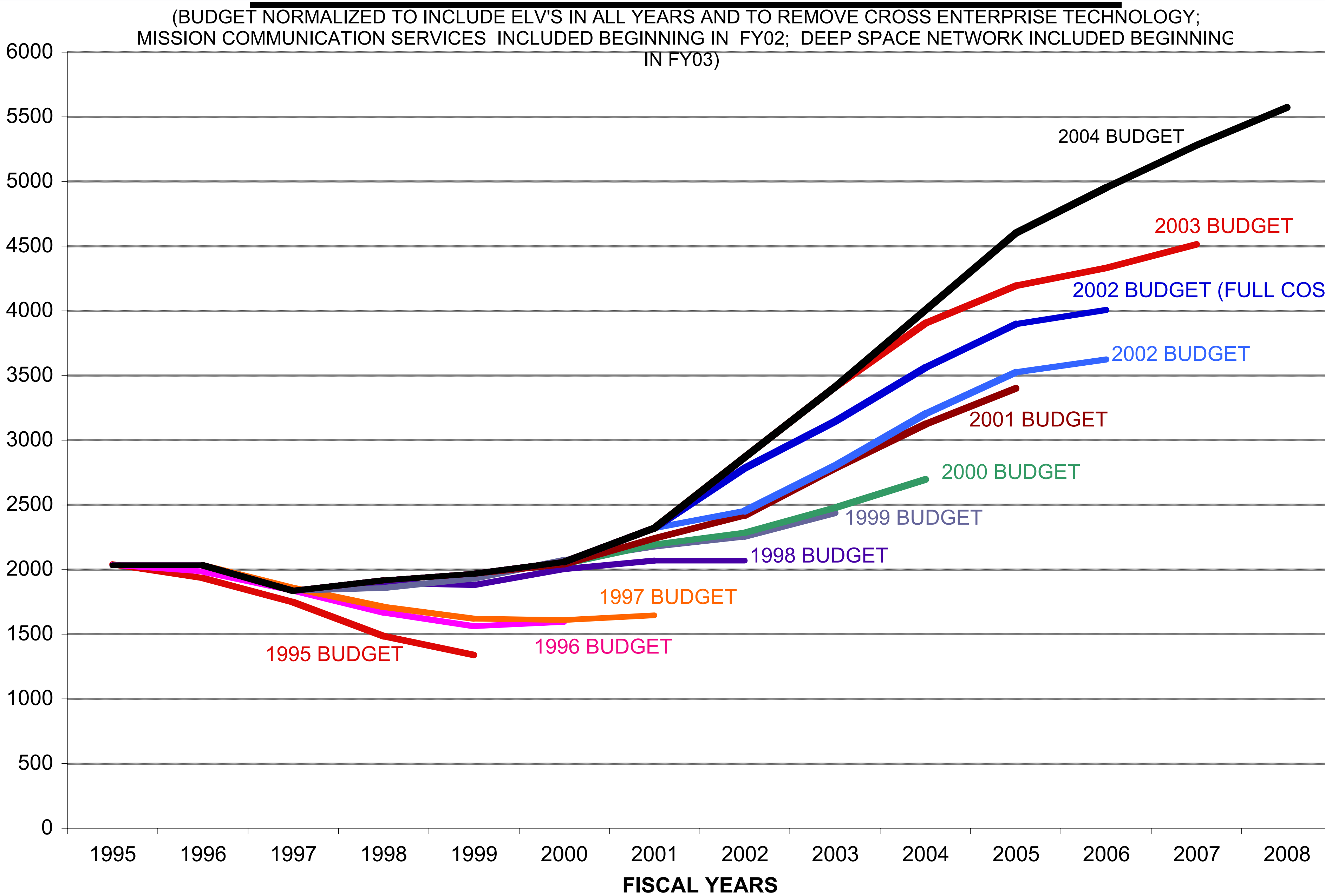
	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
TOTAL NASA	**15,000**	**15,470**	**16,044**	**16,655**	**17,297**	**17,805**
SCIENCE, AERONAUTICS & EXPLORATION	**7,100**	**7,661**	**8,269**	**8,745**	**9,201**	**9,527**
SPACE SCIENCE	3,468	4,007	4,601	4,952	5,279	5,573
EARTH SCIENCE	1,610	1,552	1,525	1,598	1,700	1,725
BIOLOGICAL & PHYSICAL RESEARCH	913	973	1,042	1,087	1,118	1,143
AERONAUTICS	949	959	932	939	934	916
EDUCATION	160	170	169	169	170	170
SPACE FLIGHT CAPABILITIES	**7,875**	**7,783**	**7,747**	**7,881**	**8,066**	**8,247**
SPACE FLIGHT	6,107	6,110	6,027	6,053	6,198	6,401
CROSSCUTTING TECHNOLOGIES	1,768	1,673	1,720	1,828	1,868	1,846
INSPECTOR GENERAL	**25**	**26**	**28**	**29**	**30**	**31**
SPACE SCIENCE AS % OF AGENCY TOTAL	*23.1*	*25.9*	*28.7*	*29.7*	*30.5*	*31.3*

Budget Increases

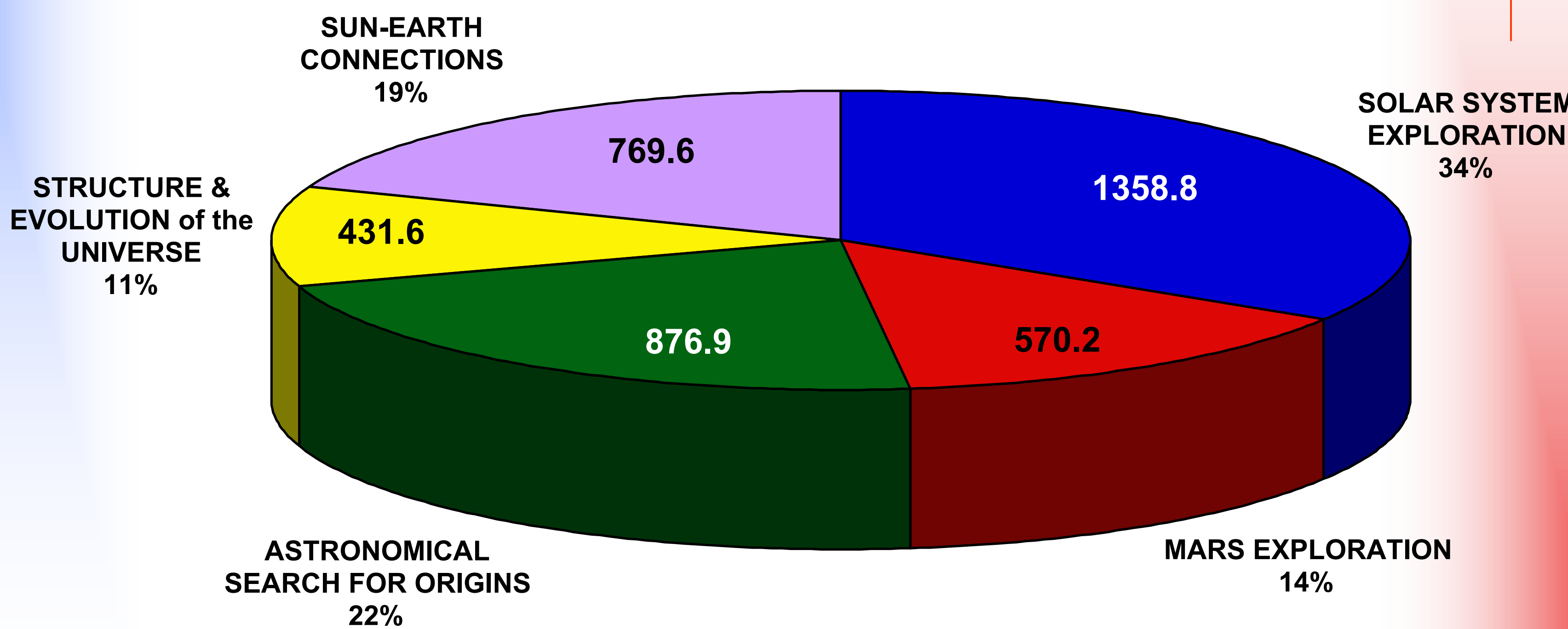
- Over the FY 2004 – FY 2007 period, the OSS budget has increased from $16.9 billion to $18.8 billion, or by $1.9 billion (11.2%)
- In FY 2008, the OSS budget exceeds $5.5 billion
- Major elements of increase:

	FY 2004-08
Total	$2.7 billion
JIMO	$2.0
Beyond Einstein	.5
Optical Comm	.2

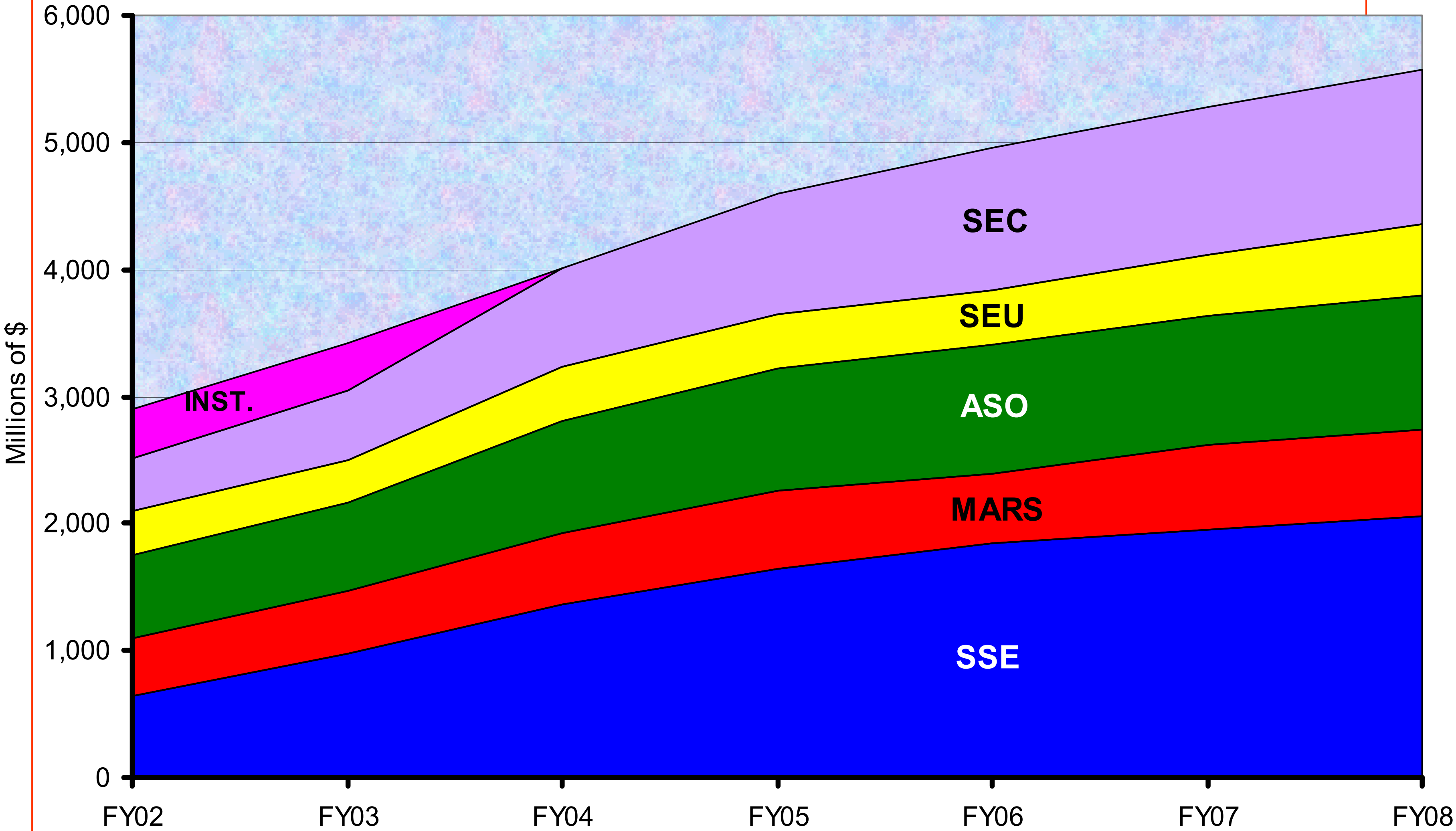
Space Science Budget History



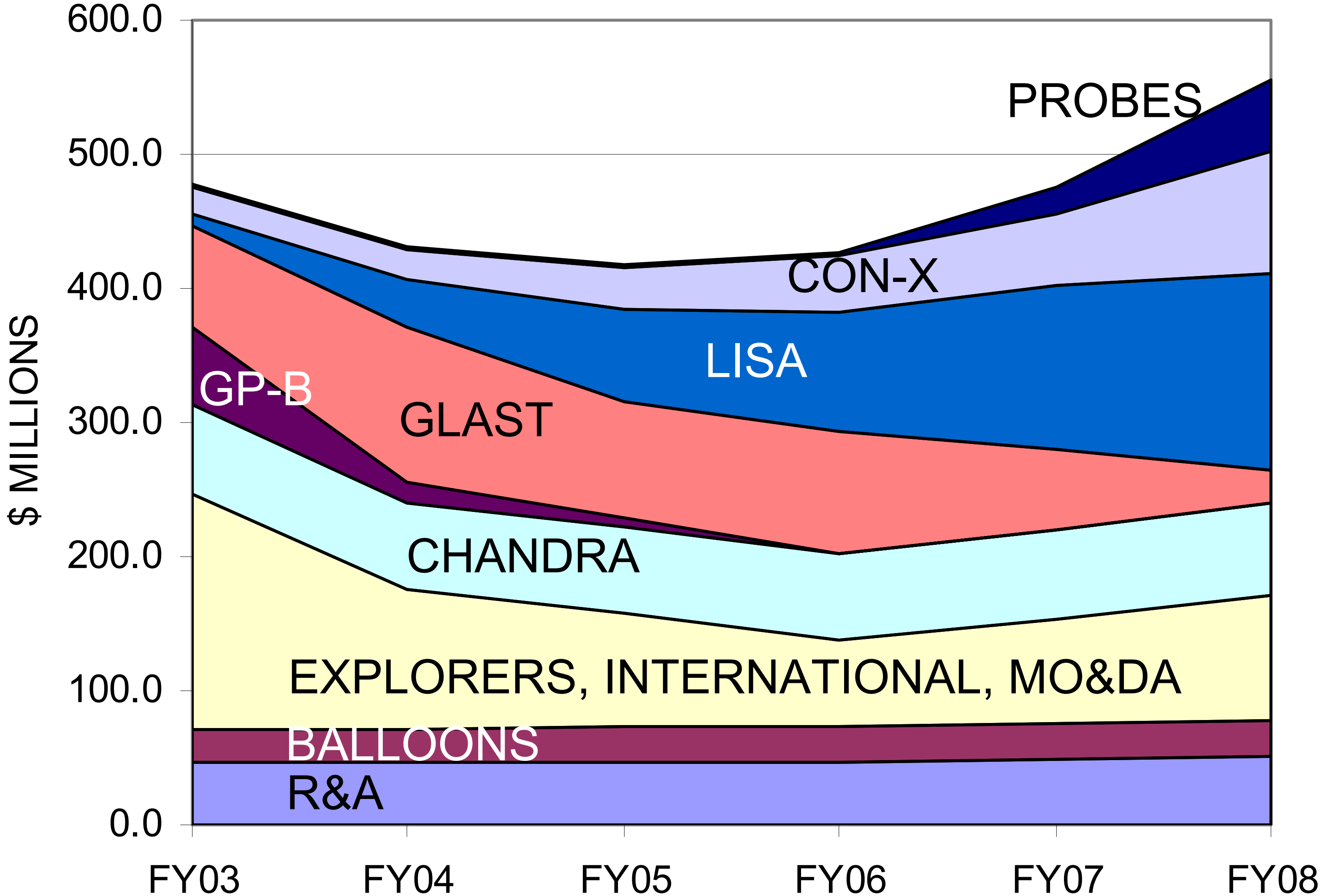
Space Science Budget
Full-Cost FY04 President's Request



FY04 Full-Cost President's Budget
(FY02 & FY03 are BAU)



FY04 Full-Cost President's SEU Budget
(FY02 & FY03 are BAU)



Space Science Budget
FY 2004 New Content

- Incorporates the existing NSI program and the new Jupiter Icy Moons Orbiter (JIMO) mission into a new initiative called Project Prometheus.
- Establishes an Optical Communications program, which enables revolutionary new data communications/transmission.
- Provides development funding for three key elements of the Beyond Einstein program: Constellation X, LISA and Einstein Probes.

Supports increased activity in priority programs

Project Prometheus

- Project Prometheus will enable vastly more robust and ambitious scientific missions by utilizing future spacecraft nuclear power capabilities.

- Nuclear power will:
  - Support more complex scientific instruments
  - Enable significantly larger and faster data communications networks
  - Allow a single spacecraft to visit multiple targets per mission
  - Eliminate dependence on gravity assists

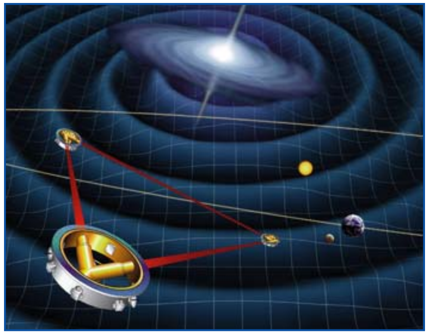
- Project Prometheus includes:
  - The Nuclear Systems Initiative announced with the President’s FY03 budget request
  - The Jupiter Icy Moons Orbiter (JIMO) mission, which is the first application of these technologies assigned to a flight mission.

Optical Communications

- Optical communications offers the potential for many orders of magnitude of improvement in communication data rate.
- Will allow for the return of the much greater quantities of scientific data.
    - Enabled by nuclear missions such as Project Prometheus (tours of multiple targets; extended orbital and surface stay times; high-power science instruments).
- Use of optical/laser communication technology will lower the cost per byte of data returned).

Beyond Einstein

- Significant expansion of efforts in NASA's Structure and Evolution of the Universe (SEU) theme, addressing its highest priorities as determined by the National Academy of Sciences' Decadal Survey.
- Funding for full development of two major missions: LISA and Constellation-X.



- Funding to initiate "Einstein Probes," a program that will begin later this decade.
    - this program consists of fully and openly competed missions (in the manner of the Discovery, Explorers, and New Frontiers programs) to conduct investigations that benefit the Beyond Einstein science objectives.

Contents of BE FY04 Budget

The President has requested $59 million in FY04 and $765 million over the next five years (FY04-08) for the Beyond Einstein Initiative.

- LISA: $35.3 million in FY04 ($5.0 million for R&A, $30.3 million for advanced technology development).
- Con-X: $23.5 million in FY04 ($23.5 million for development). Key milestones for FY04:
  - Complete build and test of an engineering model of the Spectroscopic X-ray Telescope mirror.
  - Fabricate a 70% flight size reflection grating.
  - Produce and test the second generation event driven CCD's.
  - Fabricate and begin testing of an 8x8 array with 16 channels of readout for the X-ray Microcalorimeter Spectrometer.
  - Build the first prototype unit for the Hard X-ray Telescope.